Text table 9-6.
Employment projections for core IT occupations
(Thousands)

	Employment		Change, 1996-2006			Total Job Openings
Occupation	1996	2006	Number	Percentage	Net Replacements	(growth and net replacement)
Computer scientists	212	461	249	118	19	268
Computer engineers	216	451	235	109	15	250
Systems analysts	506	1,025	520	103	34	554
Computer programmers	568	697	129	23	177	306
Total	1,502	2,634	1,133	75	245	1,378

SOURCE: U.S. Department of Commerce, *The Digital Work Force: Building Infotech Skills at the Speed of Innovation.* (Washington, DC: 1999); and U.S. Department of Labor Statistics, 1996 industry-occupation employment matrix.

Science & Engineering Indicators – 2000

levels; people from other science, engineering, and business fields; and people from nontechnical disciplines who have taken some courses in IT subjects. Many people also enter the field through continuing education programs and for-profit schools. New modes of instruction delivery, such as distance learning are being used. (See "Distance Education.")

- The job market is showing signs of responding—if imperfectly—to the tight IT labor markets. Wage increases are attracting more people to the field. A large number of initiatives around the country have been started to address the problem. Enrollments are increasing in training programs and in 4-year degree programs.

IT and Education

Information technologies are likely to have a substantial effect on the entire spectrum of education by affecting how we learn, what we know, and where we obtain knowledge and information. IT influences the creation of scientifically derived knowledge; how children learn in schools; lifelong learning by adults; and the storage of a society's cumulative knowledge, history, and culture. IT can bring new information and types of instruction into the classroom; it can provide students with new tools for finding and manipulating information; and it can provide resources that are not available in a particular geographical area. At the same time, IT may impose new costs in equipment, software, and the time it takes to learn new systems; it also threatens to disrupt existing methods of knowledge creation and transfer, as well as the archiving of knowledge.

This section reviews the role of IT in classrooms, in distance education, in the storage and dissemination of knowledge, and in the creation of new knowledge. In each of these areas, similar technologies can be applied from K–12 education to leading-edge research. Much of the attention in each of these categories, however, is directed at one level. Most discussion of IT in the classroom, for example, focuses on K–12 education. Distance education is being used most in higher education. Discussion of the creation, storage, and dissemination of knowledge focuses on the research community. Although this discussion concentrates on these areas, virtually all of the technologies discussed here can be used—and are being used—at many levels in the education/research system. Other chapters of this report discuss the use of information technology in specific parts of the education system: For example, chapter 5 discusses IT at the K–12 level.

IT in the Classroom

In recent years there has been a great deal of emphasis in the United States on increasing the use of information technologies in U.S. elementary and secondary schools (Children's Partnership 1996, McKinsey and Company 1995, NIIAC 1995, PCAST 1997). Greater use of IT at the precollege level is frequently regarded as providing the training students need to be competent members of the information society and to enjoy the benefits of information technology. Schools are expected to expose all children to information technologies so society does not become stratified into information-rich and information-poor classes. A 1992 survey of elementary and high school principals found that the three main reasons schools adopt computer technologies are to give students the experience they will need with computers for the future, to keep the curriculum and teaching methods current, and to improve student achievement (Pelgrum, Janssen, and Plomp 1993).

Assumptions about the educational benefits of IT are not universal, however. *Silicon Snake Oil: Second Thoughts on the Information Highway* (Stoll 1995) represents one critique of claims about the social payoff of IT (including educational benefits). Scholar Larry Cuban (1994) has questioned the use of computers in classrooms, and journalist Todd Oppenheimer (1997) has described the opportunity costs of spending educational funds on IT.

The fundamental dilemma of IT-based education is that it has not been proven to be more cost-effective than other forms of instruction (Cuban 1994, Kulik and Kulik 1991, Rosenberg

1997). Although real IT learning benefits have been demonstrated, we do not know whether the magnitude of those benefits is sufficiently large to justify consuming substantial resources and actively displacing other school curricula and programs.

Others (e.g., Papert 1995) suggest that the question at stake is no longer whether technology can change education or whether this change is desirable. Technology is a major factor in changing the entire learning environment, and schools will need to change in fundamental ways to keep pace.

The budget issues and educational opportunity costs associated with IT are significant. In a report to the U.S. Advisory Committee on the National Information Infrastructure, McKinsey and Company (1995) estimated that about 1.3 percent of the national school budget is spent on instructional technology. Increasing the level of IT in K–12 public schools could require raising this spending to as much as 3.9 percent of the national school budget, depending on the degree of IT intensity desired.[3] Moreover, these figures do not include IT operational expenses or the cost of teacher training—a significant factor in the effectiveness of computer-based instruction (CBI) (McKinsey and Company 1995, PCAST 1997, Ryan 1991, OTA 1995). Because school districts are under increasing fiscal stress, expanding IT resources could mean cutting other important programs. Oppenheimer (1997) details sacrifices in art, music, physical education, vocational classes, and textbook purchases that have been made so that computers could be placed in the schools. The negative effects of these sacrifices on learning and job skills are not usually considered in the growing emphasis on CBI.

Uncertainty about the effect of information technology in the classroom is not surprising. Computers are powerful tools that can be used in many different ways in education. CBI is a broad category that includes computer-assisted instruction (typically drill-and-practice exercises or tutorial instruction), computer-managed instruction (in which the computer monitors student performance and progress and guides student use of instructional materials), and computer-enriched instruction (in which the computer functions as a problem-solving tool). Computers have a variety of potential uses in education: generic information handling, real-time data acquisition, simulations, multimedia, educational games, cognitive tools, intelligent tutors, construction environments, virtual communities, information access environments, information construction environments, and computer-aided instruction (Rubin 1996). Software (courseware) for inquiry-based learning[4] is the ultimate goal of most CBI advocates and the most cognitively demanding form of learning (Kulik and Kulik 1991, McKinsey and Company 1995, PCAST 1997). Given the diversity of applications, from drill and practice exercise to participating in global environmental projects, generalizing about the costs and benefits of computers in the classroom is difficult. (See sidebar, "Innovative Education Projects.")

Diffusion of IT in Education

Over the past 20 years, computers and other information technologies have been diffused widely in the U.S. K–12 educational system. One measure of IT in schools is the ratio of students to computers. In 1998 there were approximately six students per instructional computer in public schools. (See figure 9-14.) Medium-sized schools (300–999 students) and large schools (1,000 or more students) had less access to instructional computers per student than small schools (fewer than 300 students). Schools located in cities had more students per instructional computer than schools in the urban fringes, towns, and rural areas.

Another measure is the degree to which schools are connected to the Internet. Schools have been connecting to the Internet at a rapid rate. By 1998, 89 percent of public schools were connected to the Internet—up from 35 percent in 1994. Although schools with large numbers of students in poverty and large minority populations were much less likely to be connected to the Internet a few years ago, by 1998 most of these differences had decreased sharply (NCES 1999).

The percentage of instructional rooms with access to the Internet also has been growing. In 1998, 51 percent of instructional rooms in public schools were connected to the Internet—nearly double that of 1997. As one might expect, wealthier schools tend to be better connected to the Internet. Public schools with high minority enrollments are likely to have a smaller percentage of instructional rooms connected to the Internet. Similarly, public schools with more students eligible for free or reduced-price school lunch had fewer instructional rooms wired. There are also regional differences. Schools in the Northeast had a lower proportion of rooms connected to the Internet than schools in the Southeast, Central, and West regions.

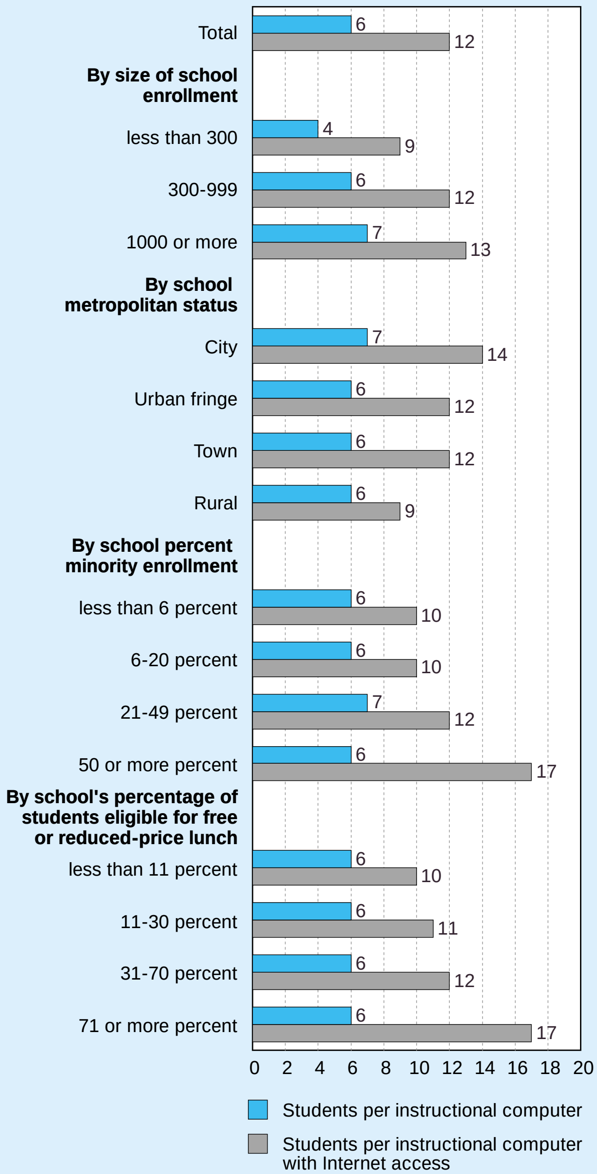
These differences do not appear to be permanent, however. Schools with high minority or subsidized lunch ratios were about as well connected to the Internet in 1998 as the most connected categories of schools were in 1997. (See appendix table 9-5.)

Schools are also upgrading their Internet connections. The percentage of schools using dial-up connections has dropped from 74 percent of public schools with Internet access in 1996 to 22 percent in 1998. (See figure 9-15.) The percentage of higher-speed connections using dedicated lines has increased from 39 percent in 1996 to 65 percent in 1998. The rapid increase in Internet connection reflects interventions through several programs to increase the use of IT in the schools. These initiatives include National Telecommunications and Information Administration programs to support novel application of information technology; NetDay volunteer efforts to connect schools and classrooms to the Internet; the e-rate pro-

[3]For example, ensuring adequate pupil-to-computer ratios and Internet connections to the school versus universal classroom deployment of full multimedia computers, Internet connections, and school networks. The McKinsey report details three alternative IT models and estimated costs.

[4]Inquiry-based learning represents active learning on the part of a student rather than passive assimilation of information that is "taught" by an instructor. Inquiry-based learning reflects active construction of models for conceptual understanding, the ability to connect knowledge to the world outside the classroom, self-reflection about one's own learning style, and a cultivated sense of curiosity. See Rubin (1996).

Figure 9-14.
Ratio of students per instructional computer and students per instructional computer with Internet access, by school characteristics: Fall 1998



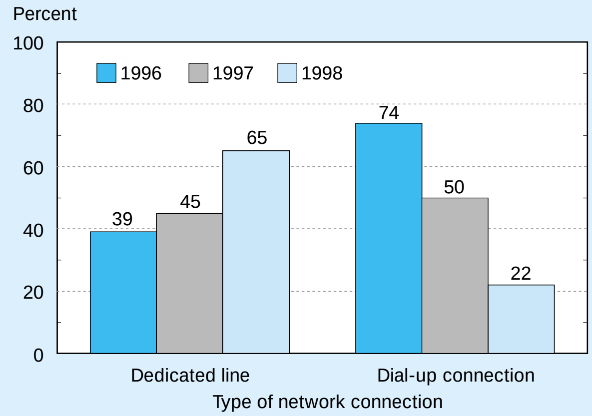
SOURCES: U.S. Department of Education, National Center for Education Statistics, Fast Response Survey System, "Internet Access in Public Schools," NCES 98-031, and "Survey on Internet Access in U.S. Public Schools, Fall 1998," FRSS 69 (1998).

Science & Engineering Indicators – 2000

gram to subsidize telecommunication charges for schools; and many other programs by private corporations and foundations.

The Campus Computing Project (1998) has found that information technologies increasingly are being used in college courses as well. E-mail, the Internet, course Web pages, simulation, and other technologies are being used in more courses every year. (See figure 9-16.) In some cases, the decision to use more IT in college courses is largely left to the

Figure 9-15.
Percentage of public schools with Internet access, by type of Internet connection: Fall 1996–98



NOTE: Data were also collected for ISDN, cable modem, and wireless connections.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Fast Response Survey System, "Advanced Telecommunications in Public Elementary and Secondary Schools, 1996," NCES 97-944, "Internet Access in Public Schools," NCES 98-031, and data from the "Survey on Internet Access in U.S. Public Schools, Fall 1998," FRSS 69, 1998.

Science & Engineering Indicators – 2000

professor. On the other hand, universities such as UCLA have required professors to establish Web pages for each course and to put syllabuses online. As with IT in K–12 education, support for the increased use of IT in college campuses has not been universal. Many professors and administrators are enthusiastic early users of the new technologies; others prefer to wait for other institutions to find out which new technologies are useful in improving the quality of education.

Many of the new information technologies being used in scholarly communication and research can be used in education as well. Scientific and scholarly literature is increasingly available online, students can learn from computer modeling and simulation, and there are opportunities to participate in scientific experiments online. The types of IT that can be incorporated into education can be expected to expand.

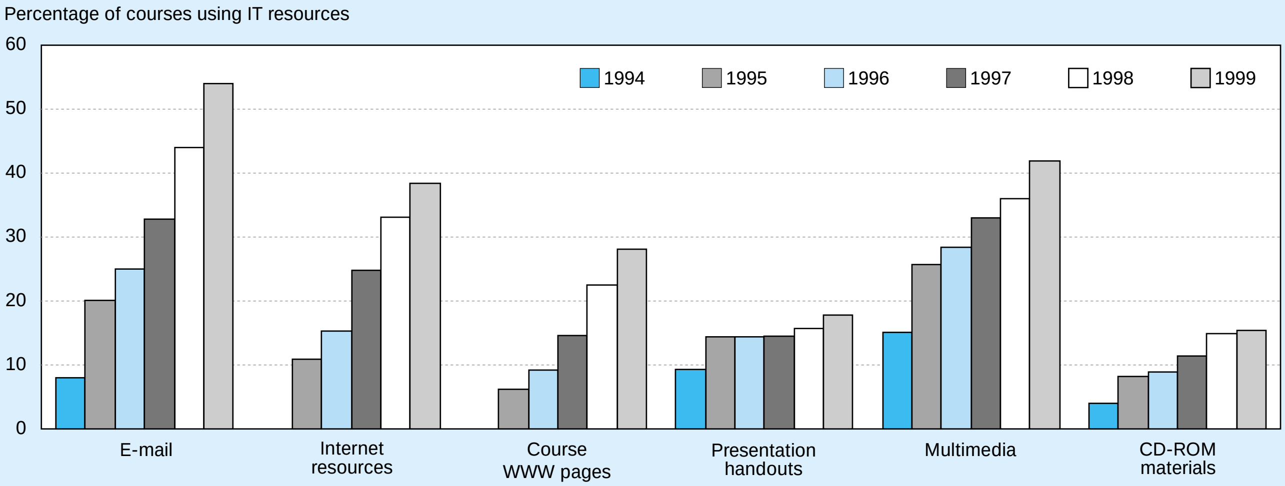
Effectiveness of IT in Education

As with the economic effects of IT, measuring the application of IT in education is much easier than measuring its effects or cost-effectiveness. Several factors explain why IT has not yet shown up in overall educational performance measures.

- There are measurement difficulties because people disagree on the appropriate ways to measure performance in education and the relevance of standardized test scores.

- It will take time for the educational system to figure out the best ways to use information technologies.

Figure 9-16.
Use of information technology in higher education instruction: 1994–99



SOURCE: Campus Computing Project (November 1999); and 1999 National Survey of Information Technology in Higher Education, available from <<http://www.campuscomputing.net/>>.

Science & Engineering Indicators – 2000

- Factors other than the technology itself, such as infrastructure support, school organization, and teacher training influence the effectiveness of the technology.
- The technologies are rapidly changing. The technologies that are available today—the Internet, multimedia and simulation software—are substantially different from those available even five years ago. Findings on the effectiveness of IT in the classroom from five years ago may be obsolete.

Many variables in the classroom influence the effectiveness of CBI in the classroom. Schofield (1995) found that the social organization of the school and classrooms affect computer-related learning, behavior, attitudes, and outcomes. Systematic understanding of the social and cognitive complexity of computer-based learning is limited. As the President's Committee of Advisors on Science and Technology (PCAST) Panel on Educational Technology noted:

> In 1995, less than 0.1 percent of our nation's expenditures for elementary and secondary education were invested to determine which educational techniques actually work, and to find ways to improve them (PCAST 1997).

A keyword search of the Educational Resources Information Center (ERIC) (http://www.accesseric.org/)—the primary bibliographic database used for educational research—yields thousands of citations related to computer-assisted instruction and student achievement. The notable characteristic of this research is its diversity: Studies range from anecdotal reports to formal experimental designs, many of which control for different sets of variables and include different types of computer use in different subject areas. Moreover, interest in the effects of computers on young people is not limited to learning and achievement. Concerns about the emotional and psychological effects of prolonged exposure to computing environments have also been raised.

Several syntheses and reviews of this literature have been carried out. Some are standard literature reviews, which can flexibly interpret the differences among studies but also may reflect the author's biases in selecting and interpreting studies. Other syntheses are "meta-analyses." Meta-analysis refers to the statistical analysis of the results of many studies to integrate the findings. Meta-analysis allows researchers to cumulate the findings of multiple studies into a single measure of outcome and estimate the magnitude of an independent variable's impact. A number of meta-analyses have been conducted on the effects of computer-based instruction.

Kulik and Kulik (1991) performed meta-analysis on 254 studies conducted between 1966 and 1986 that covered many different educational levels and instructional technologies. In a subset of this study, Kulik and Kulik analyzed 68 studies on computer-assisted instruction at the precollege level; they found that students using computer-based instruction scored (on average) in the 64th percentile on measures of learning and achievement, compared to the 50th percentile for students in a traditional class.

Ryan's (1991) meta-analysis of 40 studies[5] conducted between 1984 and 1989 found the average K–6 student using a microcomputer as an instructional tool performed in the 62nd percentile on tests, compared to the 50th percentile for the average K–6 student who did not use a microcomputer. Ryan

[5]Ryan also had a precise set of stringent selection criteria, including requirements that the study reflect experimental or quasi-experimental design, that the sample size be at least 40 students (a minimum of 20 students in the treatment and control groups), and that the treatment last eight weeks or longer.

also evaluated several sets of variables other than CBI that may have had an impact on the size of the effect. Of these variables, only the degree of teacher pretraining was statistically significant. In experimental groups in which teachers had fewer than 10 hours of computer pretraining, the effect size of CBI was negligible and, in some instances, negative. In groups in which teacher pretraining exceeded 10 hours, students in the experimental group performed at the equivalent of the 70th percentile—equivalent to a gain of half a school year gain over the control. These findings reinforce those of other studies that identify the crucial role of teacher preparedness in effective CBI (PCAST 1997; OTA 1995).

Schacter (1999) reviewed seven studies of educational technology:

- a meta-analysis of more than 500 studies (Kulik 1999);
- a review of 219 research studies from 1990 to 1997 (Sivin-Kachala 1998);
- an evaluation of the Apple Classrooms of Tomorrow (Baker, Gearhart, and Herman 1994);
- a study of West Virginia's Basic Skills/Computer Education statewide program (Mann et al. 1999);
- a national study of the effects of simulation and higher order thinking technologies on math achievement (Wenglinsky 1998);
- work on collaborative computer application in schools (Scardamalia and Bereiter 1996); and
- the work of the learning and epistemology group at MIT (Harel 1990; Harel and Papert 1991).

Collectively, these studies cover more than 700 empirical research studies and focus on the most recent work. On the basis of this review, Schacter (1999) concludes that "students with access to: (a) computer-assisted instruction or (b) integrated learning systems technology or (c) simulations and software that teach higher-order thinking or (d) collaborative networked technologies or (e) design and programming technologies show positive gains in achievements on research constructed tests, standardized tests, and national tests." Schacter also found evidence, however, that learning technology is less effective or ineffective when learning objectives are unclear and the purpose of the technology is unfocused.

Innovative Education Projects

Several special projects merit note. The Higher Order Thinking Skills (HOTS) Program, for example, is an intervention program for economically disadvantaged students in the fourth through seventh grades. Students were taken from their traditional classrooms and taught through an innovative curriculum that integrated computer-assisted instruction, drama, and the Socratic method. Students in the HOTS Program outperformed other disadvantaged students in a control group on all measures and had double the national average gains on standardized tests in reading and mathematics (Costa and Liebmann 1997).

The Buddy Project in Indiana, in which students in some classrooms were given home computers, also reported highly positive results across a variety of skills. Similar results were reported for the Computers Helping Instruction and Learning Development (CHILD) program in Florida, an elementary school program that emphasized student empowerment, teacher training and teamwork, and independent learning (ETS 1997). These studies suggest that the use of computers in enriched, nontraditional learning environments might achieve the fundamental changes in student learning that advocates of computer-based instruction desire.

Another innovative IT-based program is the Global Learning and Observations to Benefit the Environment (GLOBE) program (<<http://www.globe.gov/>>)—a worldwide network of students, teachers, and scientists working together to study and understand the global environment. Students and teachers from more than 7,000 schools in more than 80 countries are working with research scientists to learn more about our planet. GLOBE students make environmental observations at or near their schools and report their data through the Internet. Scientists use GLOBE data in their research and provide feedback to students to enrich their science education. Global images based on GLOBE student data are displayed on the World Wide Web, enabling students and other visitors to visualize the student environmental observations.

Distance Education

Distance education is not new. An estimated 100 million Americans have taken distance study—mostly correspondence courses—since 1890 (Distance Education and Training Council 1999), and in the 1960s there was widespread optimism about the use of television in education. Information technologies are providing significant new tools for distance education. Many schools are establishing distance education programs for the first time or expanding their existing distance education courses.

In online distance courses, students are likely to use e-mail to communicate with instructors and fellow students. The instructor typically sends "lectures" via e-mail or posts them on a Web page, and students submit assignments and have "discussions" via e-mail. Courses often supplement textbooks with Web-based readings. These courses may also meet in a chat room at a certain time for online discussions. Classes may also have online bulletin boards or Web conferences in which people ask and respond to questions over time. In the not-too-distant future, as Internet bandwidth increases, video lectures and videoconferencing will become more common additions to the online courses. Some classes may also use more elaborate systems called MUD/MOOs[6] for group interaction as well as many groupware programs that often involve simultaneous viewing of graphics and use of a shared writing space (i.e., electronic white board) (Kearsley 1997). Other classes may make use of computer simulations over the Internet.

Distance education offers several potential advantages. It may allow students to take courses not available in their geographical area, and it may allow students to take courses in a way that fits in with their career and family life. It makes education more available to working students with Internet access—especially older, mid-career students and those who have family responsibilities. For universities, it offers a way to expand enrollment without increasing the size of their physical plant.

Although distance education traditionally is regarded as education or training courses delivered to remote locations, distance education techniques—especially online education—can be incorporated as part of on-campus instruction as well. Universities are finding that significant numbers of on-campus students will take distance education courses when such courses are offered. At the University of Colorado at Denver, for example, more than 500 of 609 students enrolled in distance-education courses were also enrolled in regular courses (Guernsey 1998). Online courses can be more convenient for on-campus students, allowing them to better fit courses into their schedules. Such courses can also allow professors to augment course material with Web-based materials or guest lecturers in remote sites.

Trends in Distance Education

- ♦ The National Center for Education Statistics has conducted two surveys of distance education in post-secondary education institutions, the first in the fall of 1995 and the second in 1997/98 (NCES 1999b). The first survey covered only higher education institutions, while the second survey covered all post-secondary educational institutions. These surveys document that distance education is now a common feature of many higher education institutions and is growing rapidly. The majority of courses are at the undergraduate level and are broadly distributed across academic subjects.

- ♦ The number of higher education institutions offering distance education is growing. In the fall of 1995, 33 percent of 2-year and 4-year higher education institutions offered distance education courses. By 1997/98, the figure had grown to 44 percent. (See appendix table 9-6.) In 1995, 62 percent of public 4-year institutions offered distance education; by 1997/1998, 79 percent offered distance education. Private 4-year colleges are much less likely to offer distance education, but are also increasing their use of it. The percentage of private 4-year colleges offering distance education increased from 12 percent in 1995 to 22 percent in 1997/98.

- ♦ Distance education course and enrollments are growing more rapidly than the number of institutions offering distance education. The number of courses offered in 2-year and 4-year higher education institutions doubled from 25,730 in 1994/95 to 52,270 in 1997/98. (See appendix table 9-7.) The increases were fairly similar across all categories of higher education institutions (2-year and 4-year schools, public and private institutions, and all size categories). Course enrollments were also up sharply, more than doubling from 753,640 in 1994/95 to 1,632,350 in 1997/98 (NCES 1999b).

- ♦ Of those higher education institutions that offer distance education, the percentage that offer degrees that can be completed exclusively with distance education courses has remained essentially constant, 22 percent in 1997/98 compared to 23 percent in 1995 (NCES 1999b).

- ♦ There has been a significant change in the technologies used for distance education. (See appendix table 9-8.) In 1995, the most widely used technologies were two-way interactive video (57 percent) and one-way prerecorded video (52 percent). These were still widely used in 1997/98 at 56 percent and 48 percent, respectively. Internet-based courses, however, expanded greatly. The percentage of institutions offering Internet courses using asynchronous (not requiring student participation at any set time of day or week) computer-based instruction was 60 percent in 1997/98. The percentage of institutions that offered Internet courses using synchronous (real-time) computer-based instruction was 19 percent in 1997/98 (NCES 1999b).

Significance of Distance Education

Despite substantial and growing experience with online education, there have been relatively few thorough assessments. Frank Mayadas of the Sloan Foundation (which supports asynchronous learning[7]) suggests that because online education provides access to education to a new student population, it does not need to be directly compared to on-campus education (Miller, n.d.). Instead, asynchronous learning should be assessed according to degree of access provided, the extent to which learning meets or exceed goals set by faculty and the institution, the extent to which it is a satisfying experience for faculty, its cost-effectiveness, and its student satisfaction.

There is evidence that, at least in some circumstances, online education can be very effective. The rapid growth and success of some online education providers suggests that they are providing acceptable learning experiences. At the same time, there are many other case studies that report at least initial frustrating experiences with online education.

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[6]MUD stands for "multiple user dimension, dialogue, or dungeon." MOO stands for "MUD, object oriented."

[7]Asynchronous learning refers to distance learning that uses technologies that allow participants to interact without having to be available at the same time.

Kearsley, Lynch, and Wizer (1995) reviewed the literature that examines the use of computer conferencing in higher education and found that, in comparison with traditional classes, student satisfaction with online courses is higher, measures of student achievement are the same or better, and there is usually more discussion among students and instructors in a course.

Schutte (1997) reported on an experiment carried out during a fall 1996 social statistics course at California State University, Northridge, in which students were randomly divided into two groups—one taught in a traditional classroom and the other taught virtually on the World Wide Web. Text, lectures, and exams were standardized between the two groups. Schutte found that, contrary to expectations, the virtual class scored an average of 20 percent higher than the traditional class on both examinations.

At the same time, distance education raises issues concerning broader effects on the university. Although online education may expand the pool of people who have access to education, it also may take students away from traditional education, and some scholars express concern that it will undermine the traditional college experience. Some people question whether the quality of distance education can match that of face-to-face instruction. Moreover, creating the kind of intellectual or social community that characterize colleges may be much harder through distance learning.

Distance education also brings universities into competition with each other in a new way. Because distance education courses are available to anyone, anywhere, they allow universities to compete for students in other geographic areas. Top-tier universities such as Stanford and Duke are beginning to market Internet-based master's degrees to national audiences. New distance education–based universities—such as Jones International University (<<http://www.jonesinternational.edu>>), the first online-only university to gain accreditation; the University of Phoenix online (<<http://online.uophx.edu>>); and the Western Governors University (<<http://www.wgu.edu>>)—are also marketing courses that compete with universities and community colleges that have in the past been providers of continuing education services in their region. Others see opportunities to market American university degrees to large potential student populations abroad. The reverse is also happening. The United Kingdom's Open University, which has established a good reputation as a provider of distance education in the U.K. since 1971, has started an operation in the United States (Blumenstyk 1999a).

In addition, distance education is creating new markets for companies selling course materials and software to assist in online courses (Blumenstyk 1999b). Publishers such as McGraw-Hill and software companies such as Microsoft and Oracle have developed and are marketing online courses (Morris 1999).

Some people regard distance education technologies as providing new tools to professors. Others foresee mass production education, in which packaged multimedia courses will reduce the importance of professors (Noble 1998). As one indicator of concern, more than 850 faculty members at the University of Washington signed a letter to Governor Gary Locke protesting the state's plans for investing in information technology (Monaghan 1998). The expanding and potentially lucrative new market for online course materials has also raised the issue of whether professors or the university should own the intellectual property embodied in online courses. The American Association of University Professors (AAUP) has taken the position that professors rather than institutions should retain primary property rights for online course materials (Schneider 1999) and has questioned the accreditation of Jones International University (Olsen 1999).

The issues raised by IT in education are still in their infancy and will probably take years to resolve.

IT, Research, and Knowledge Creation

Information technology is having broad and substantial effects on research and the creation of knowledge. IT facilitates:

- ♦ new ways of communicating and storing scholarly information;
- ♦ new methods of research and new fields of science; and
- ♦ new forms of scientific collaboration.

The effects of IT on research and knowledge creation are important for two reasons. First, they have significant effects on the research community, which in turn affects innovation and education in society. Second, many applications of IT that have been used first in the research community, such as e-mail and the World Wide Web, have later diffused more widely and have had major effects outside of the research community.

Scholarly Communication

In his 1945 *Atlantic Monthly* article, Vannevar Bush illustrated how helpful it would be to researchers to have access at their desk to the great body of the world's knowledge. In the past few years, that vision has come much closer to reality. The Internet and the World Wide Web, originally developed as tools for scientific communication, have become increasingly powerful. An increasing amount of scholarly information is stored in electronic forms and is available through digital media—primarily the World Wide Web.

Scholars derive many advantages from having scholarly information in digital form. They can find information they want more easily using search tools. They can get the information without leaving their desks, and they do not have to worry about journals being missing from the library. They can get more complete information because electronic publications are not constrained by page limits as printed journals commonly are. Multimedia presentations and software can be combined with text, enriching the information and facilitating further work with it. Additional references, comments from other readers, or communication with the author can be a mouse-click away.